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PREPARATION OF ϵ -PHASE SILVER VANADIUM OXIDE FROM γ -PHASE SVO STARTING MATERIAL.

CROSS REFERENCE TO RELATED APPLICATION

10 This application claims priority based on
provisional application Serial No. 60/254,918, filed
December 12, 2000.

BACKGROUND OF THE INVENTION

15 1. FIELD OF THE INVENTION

This invention relates to the conversion of chemical energy to electrical energy. More particularly, this invention relates to the preparation of an improved cathode active material for non-aqueous

20 lithium electrochemical cells, and still more particularly, a cathode active ε -phase silver vanadium oxide (SVO, $\text{Ag}_2\text{V}_4\text{O}_{11}$) prepared using a γ -phase silver vanadium oxide ($\text{Ag}_1\text{.}5\text{V}_2\text{O}_5$) starting material.

25 implantable electrochemical cell, for example of the type powering a cardiac defibrillator, where the cell may run under a light load for significant periods interrupted from time to time by high rate pulse discharges.

30 The reaction of γ -phase SVO with a source of silver produces ϵ -phase SVO that possesses a lower surface area than SVO produced from other vanadium-containing starting materials. The relatively low surface area of this new ϵ -phase SVO material results in greater long 35 term stability for the cathode active material in

5 comparison to other forms of SVO with higher specific surfaces areas.

2. PRIOR ART

10 The prior art discloses many processes for manufacturing SVO; however, they result in a product with greater surface area than the material prepared by the current invention.

15 Specifically, U.S. Patent No. 4,391,729 to Liang et al. discloses the preparation of silver vanadium oxide by a thermal decomposition reaction of silver nitrate with vanadium oxide conducted under an air atmosphere. This decomposition reaction is further detailed in the publication: Leising, R.A.; Takeuchi, E.S. *Chem. Mater.* 1993, 5, 738-742, where the synthesis of SVO from silver 20 nitrate and vanadium oxide under an air atmosphere is presented as a function of temperature. In another reference: Leising, R.A.; Takeuchi, E.S. *Chem. Mater.* 1994, 6, 489-495, the synthesis of SVO from different silver precursor materials (silver nitrate, silver nitrite, silver oxide, silver vanadate, and silver carbonate) is described. The product active materials 25 of this latter publication are consistent with the formation of a mixture of SVO phases prepared under argon, which is not solely ϵ -phase $\text{Ag}_2\text{V}_4\text{O}_{11}$.

30 Also, the preparation of SVO from silver oxide and vanadium oxide is well documented in the literature. In the publications: Fleury, P.; Kohlmuller, R.C.R. *Acad. Sci. Paris* 1966, 262C, 475-477, and Casalot, A.; Pouchard, M. *Bull Soc. Chim. Fr.* 1967, 3817-3820, the 35 reaction of silver oxide with vanadium oxide is

5 described. Wenda, E. *J. Thermal Anal.* 1985, 30, 89-887, present the phase diagram of the V_2O_5 - Ag_2O system in which the starting materials are heated under oxygen to form SVO, among other materials. Thus, Fleury and Kohlmuller teach that the heat treatment of starting
10 materials under a non-oxidizing atmosphere (such as argon) results in the formation of SVO with a reduced silver content.

In U.S. Patent No. 5,955,218 to Crespi et al., the process of heat-treating SVO prepared by a thermal
15 decomposition reaction to improve the electrochemical performance of the material is disclosed. In this patent, thermal decomposition SVO prepared according to U.S. Patent Nos. 4,310,609 and 4,391,729, both to Liang et al., under an air atmosphere at a somewhat lower
20 temperature of 360°C is described. However, the '218 patent to Crespi et al. demonstrates that adding a second heat treatment step increases the crystallinity of the resulting active material. The present invention is concerned with the product active material's surface
25 area, and not necessarily its crystallinity.

U.S. Patent No. 5,221,453 to Crespi teaches a method for making an electrochemical cell containing SVO, in which the cathode active material is prepared by a chemical addition reaction of an admixed 2:1 mole
30 ratio of $AgVO_3$ and V_2O_5 heated in the range of 300°C. to 700°C. for a period of 5 to 24 hours. Crespi does not discuss γ -phase SVO in the context of this invention. Therefore, the ϵ -phase material described by the current invention could not be manufactured by this process.

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5 U.S. Patent Nos. 6,130,005 and 5,955,218, both to Crespi et al., relate to heat treated silver vanadium oxide materials, for example, γ -phase SVO heat treated to form decomposition-produced SVO (dSVO). The starting material does not appear to be heated for further
10 combination with a source of silver or other metal. Also, U.S. Patent No. 5,895,733 to Crespi et al. shows a method for synthesizing SVO by using AgO and a vanadium oxide as starting materials. However, the result is not a low surface area ϵ -phase SVO cathode material, as
15 disclosed in the current invention.

U.S. Patent No. 5,545,497 to Takeuchi et al. teaches cathode materials having the general formula of $\text{Ag}_x\text{V}_2\text{O}_y$. Suitable materials comprise a β -phase SVO having in the general formula $x = 0.35$ and $y = 5.18$ and a γ -phase SVO having $x = 0.74$ and $y = 5.37$, or a mixture of the phases thereof. Such SVO materials are produced by the thermal decomposition of a silver salt in the presence of vanadium pentoxide. In addition, U.S. Patent No. 6,171,729 to Gan et al. shows exemplary
20 alkali metal/solid cathode electrochemical cells in which the cathode may be an SVO of β -, γ - or ϵ -phase materials. However, none of Gan et al.'s methods are capable of producing a low surface area ϵ -phase cathode material, as per the current invention.
25

30 Therefore, based on the prior art, there is a need to develop a process for the synthesis of mixed metal oxides, including silver vanadium oxide, having a relatively low surface area. An example is a low surface area SVO prepared using a silver-containing
35 compound and γ -phase SVO as starting materials. The

A DOCUMENT REPORT

5 product ϵ -phase SVO is a cathode active material useful for non-aqueous electrochemical cells having enhanced characteristics, including the high pulse capability necessary for use with cardiac defibrillators.

10 SUMMARY OF THE INVENTION

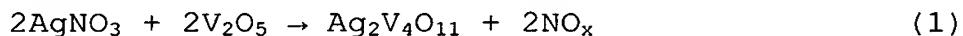
The current invention relates to the preparation of an improved cathode active material for non-aqueous lithium electrochemical cells, and in particular, a cathode active material that contains ϵ -phase SVO prepared using a γ -phase SVO starting material. The reaction of γ -phase SVO with a source of silver produces ϵ -phase SVO possessing a lower surface area than ϵ -phase SVO produced from other vanadium-containing starting materials. The present synthesis technique is not, however, limited to silver salts since salts of copper, magnesium and manganese can be used to produce relatively low surface area metal oxide active materials as well. The relatively low surface area of the ϵ -phase SVO material provides an advantage in greater long term stability when used as an active cathode material compared to SVO with a higher specific surface area.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

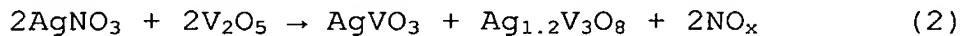
The current invention discloses that reacting a γ -phase SVO material with a source of silver, or other suitable metal salt, produces pure ϵ -phase SVO ($\text{Ag}_2\text{V}_4\text{O}_{11}$). This product material possesses a relatively lower surface area in comparison to active materials synthesized by a thermal decomposition reaction under an

5 oxidizing atmosphere. Decreased surface area is an unexpected result.

10 The thermal reaction of silver nitrate with vanadium oxide under an air atmosphere is a typical example of the preparation of silver vanadium oxide by a decomposition reaction. This reaction is set forth below in Equation 1:

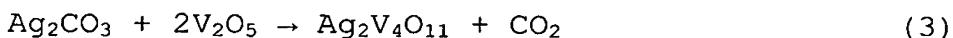


15 The physical characteristics of SVO material (i.e. particle morphology, surface area, crystallinity, etc.) produced by this reaction are dependent on the temperature and time of reaction. In addition, the reaction environment has a dramatic effect on the 20 product material. The same reaction of silver nitrate with vanadium oxide conducted under an argon atmosphere is depicted below in Equation 2:



25 Thus, the synthesis of SVO under an inert atmosphere results in the formation of a mixture of silver vanadate (AgVO_3) and γ -phase SVO ($\text{Ag}_{1.2}\text{V}_3\text{O}_8$). This is described in the above-referenced publication by 30 Leising, R.A.; Takeuchi, E.S. *Chem. Mater.* 1994, 6, 489-495. As reported by Leising et al., a mixture of material phases is less suitable than a single ϵ -phase SVO ($\text{Ag}_2\text{V}_4\text{O}_{11}$) as a cathode active material for lithium 35 electrochemical cells. For this reason, argon is typically not preferred for synthesis of SVO cathode active material.

5 A more benign preparation technique for ϵ -phase SVO from vanadium oxide and silver carbonate (Ag_2CO_3) according to Equation 3 below results in the release of CO_2 gas, which is a nontoxic byproduct. However, the specific surface area of the product SVO is also higher
 10 than the surface area of SVO prepared from silver nitrate. This is shown below in Table 1.



15 Thus, a synthesis technique for SVO using vanadium oxide and either silver oxide or silver carbonate, or other preferred metal salts, while eliminating the formation of toxic NO_x byproduct, results in an SVO material with a higher specific surface area than SVO
 20 produced from vanadium oxide and silver nitrate.

Table 1
 Specific Surface Area of ϵ -Phase SVO

Starting Materials	Synthesis Temperature	BET Surface Area
$\text{V}_2\text{O}_5 + \text{AgNO}_3$	500°C.	0.42 m^2/g
$\text{V}_2\text{O}_5 + 0.5\text{Ag}_2\text{O}$	500°C.	0.64 m^2/g
$\text{V}_2\text{O}_5 + 0.5\text{Ag}_2\text{CO}_3$	500°C.	0.81 m^2/g
$\text{Ag}_{1.2}\text{V}_3\text{O}_{8.1} + 0.15\text{Ag}_2\text{O}$	500°C.	0.54 m^2/g
$\text{Ag}_{1.2}\text{V}_3\text{O}_{8.1} + 0.15\text{Ag}_2\text{CO}_3$	500°C.	0.44 m^2/g

25

The present invention is an alternate preparation synthesis that does not produce noxious by-products, such as NO_x and, additionally, results in an active

5 material with a desirable relatively low surface area. Benefits attributed to the present synthesis process for the formation of a cathode active material are illustrated in the following examples:

10 Example 1

In contrast to the prior art syntheses described above, SVO of the present invention is prepared using γ -phase SVO ($\text{Ag}_{1.2}\text{V}_3\text{O}_{8.1}$) as a starting material instead of V_2O_5 . In particular, a 12.90 gram sample of $\text{Ag}_{1.2}\text{V}_3\text{O}_{8.1}$ 15 was combined with a 1.09 gram sample of Ag_2O , and heated to 500°C. under a flowing air atmosphere for about 16 hours. The sample was then cooled, mixed and reheated under a flowing air atmosphere at about 500°C. for about 24 hours. At this point, the material was cooled and 20 analyzed by x-ray powder diffraction and BET surface area measurements. The x-ray powder diffraction data confirmed the formation of ϵ -phase SVO ($\text{Ag}_2\text{V}_4\text{O}_{11}$). The material displayed a BET surface area of 0.54 m^2/g .

25 Comparative Example 1

As a comparison, SVO was prepared by a prior art combination reaction. In particular, a 9.00 gram sample of V_2O_5 was combined with a 5.73 gram sample of Ag_2O , and 30 heated to about 500°C. under a flowing air atmosphere for about 16 hours. The sample was then cooled, mixed and reheated under a flowing air atmosphere at about 500°C. for about 24 hours. At this point the material was cooled and analyzed by x-ray powder diffraction and 35 BET surface area measurements. The material displayed a BET surface area of 0.64 m^2/g , which is significantly

5 higher than the specific surface area of the material prepared in Example 1.

Example 2

10 ϵ -phase SVO according to the present invention was also prepared using a γ -phase SVO starting material in combination with silver carbonate. In particular, a 5.00 gram sample of $\text{Ag}_{1.2}\text{V}_3\text{O}_{8.1}$ was combined with a 0.50 gram sample of Ag_2CO_3 , and heated to about 500°C. under a
15 flowing air atmosphere for about 16 hours. The sample was then cooled, mixed and reheated under a flowing air atmosphere at about 500°C. for about 24 hours. At this point, the material was cooled and analyzed by x-ray powder diffraction and BET surface area measurements.
20 The x-ray powder diffraction data confirmed the formation of ϵ -phase SVO ($\text{Ag}_2\text{V}_4\text{O}_{11}$), while the material displayed a BET surface area of 0.44 m^2/g .

Comparative Example 2

25 As a comparison to Example 2, SVO was prepared using V_2O_5 and Ag_2CO_3 . In particular, a 15.00 gram sample of V_2O_5 was combined with a 11.37 gram sample of Ag_2CO_3 , and heated to about 450°C. under a flowing air
30 atmosphere for about 16 hours. The sample was then cooled, mixed and reheated under a flowing air atmosphere at about 500°C. for about 24 hours. At this point the material was cooled and analyzed by x-ray powder diffraction and BET surface area measurements.
35 The material displayed a BET surface area of 0.81 m^2/g , which is nearly twice the specific surface area of the material prepared in Example 2.

5

Example 3

Copper silver vanadium oxide or CSVO ($\text{Cu}_{0.2}\text{Ag}_{0.8}\text{V}_2\text{O}_{5.6}$) was prepared according to the present invention using γ -phase SVO as a starting material in combination with copper(II) oxide. In particular, a 1.80 gram sample of $\text{Ag}_{1.2}\text{V}_3\text{O}_{8.1}$ was combined with a 0.10 gram sample of CuO , and heated to about 450°C. under a flowing air atmosphere for about 16 hours. The sample was then cooled, mixed and reheated under a flowing air atmosphere at about 500°C. for about 24 hours. At this point, the material was cooled and analyzed by BET surface area measurements. The material displayed a BET surface area of 0.31 m^2/g .

20

Comparative Example 3

As a comparison to the product of Example 3, CSVO was prepared via the prior art decomposition method using V_2O_5 , $\text{Cu}(\text{NO}_3)_2$ and AgNO_3 . In particular, a 1.36 gram sample of V_2O_5 was combined with a 0.99 gram sample of AgNO_3 and a 0.34 gram sample of $\text{Cu}(\text{NO}_3)_2 \cdot 2.5\text{H}_2\text{O}$, and heated to about 400°C. under a flowing air atmosphere for about 16 hours. The sample was then cooled, mixed and reheated under a flowing air atmosphere at about 500°C. for about 44 hours. At this point, the product material was cooled and analyzed by BET surface area measurement. The material displayed a BET surface area of 0.45 m^2/g , which is significantly higher than the specific surface area of the CSVO material prepared in Example 3. Thus, in addition to the toxic implications of released NO_x gas, the preparation of CSVO by the

5 prior art method provides a material with a higher specific surface area than the new preparation technique.

The above detailed description and examples are intended for the purpose of illustrating the invention, 10 and are not to be construed as limiting. For example, starting materials other than silver oxide and silver carbonate are reacted with γ -phase silver vanadium oxide to form ϵ -phase silver vanadium compounds. The list includes: silver lactate ($\text{AgC}_3\text{H}_5\text{O}_3$, T_m 120°C.), silver 15 triflate (AgCF_3SO_3 , T_m 286°C.), silver pentafluoropropionate ($\text{AgC}_3\text{F}_5\text{O}_2$, T_m 242°C.), silver laurate ($\text{AgC}_{12}\text{H}_{23}\text{O}_2$, T_m 212°C.), silver myristate ($\text{AgC}_{14}\text{H}_{27}\text{O}_2$, T_m 211°C.), silver palmitate ($\text{AgC}_{16}\text{H}_{31}\text{O}_2$, T_m 209°C.), silver stearate ($\text{AgC}_{18}\text{H}_{35}\text{O}_2$, T_m 205°C.), silver 20 vanadate (AgVO_3 , T_m 465°C.), copper oxide (CuO , T_m 1,446°C.), copper carbonate (Cu_2CO_3), manganese carbonate (MnCO_3), manganese oxide (MnO , T_m 1,650°C.), magnesium carbonate (MgCO_3 , T_d 350°C.), magnesium oxide (MgO , T_m 2,826°C.), and combinations and mixtures thereof.

25 While the starting materials are described as being heated to a preferred temperature of about 500°C., it is contemplated by the scope of the present invention that suitable heating temperatures range from about 300°C. to about 550°C., depending on the specific starting 30 materials. Also, heating times for both the first and second heating step range from about 5 hours to about 30 hours. Longer heating times are required for lower heating temperatures. Further, while the present invention has been described in the examples as 35 requiring two heating events with an ambient mixing in

400-500-1000-1200-1500

5 between, that is not necessarily imperative. Some synthesis protocols according to the present invention may require one heating step with periodic mixing, or multiple heating events with periodic ambient mixing.

10 The product mixed metal oxides according to the present invention include: ϵ -phase SVO ($\text{Ag}_2\text{V}_4\text{O}_{11}$), CSVO ($\text{Cu}_{0.2}\text{Ag}_{0.8}\text{V}_2\text{O}_{5.6}$), MnSVO ($\text{Mn}_{0.2}\text{Ag}_{0.8}\text{V}_2\text{O}_{5.8}$), and MgSVO ($\text{Mg}_{0.2}\text{Ag}_{0.8}\text{V}_2\text{O}_{5.6}$). The use of the above mixed metal oxides as a cathode active material provides an electrochemical cell that possesses sufficient energy 15 density and discharge capacity required to meet the vigorous requirements of implantable medical devices. These types of cells comprise an anode of a metal selected from Groups IA, IIA and IIIB of the Periodic Table of the Elements. Such anode active materials 20 include lithium, sodium, potassium, etc., and their alloys and intermetallic compounds including, for example, Li-Mg, Li-Si, Li-Al, Li-B and Li-Si-B alloys and intermetallic compounds. The preferred anode comprises lithium. An alternate anode comprises a 25 lithium alloy such as a lithium-aluminum alloy. The greater the amount of aluminum present by weight in the alloy, however, the lower the energy density of the cell.

30 The form of the anode may vary, but preferably the anode is a thin metal sheet or foil of the anode metal, pressed or rolled on a metallic anode current collector, i.e., preferably comprising titanium, titanium alloy or nickel, to form an anode component. Copper, tungsten and tantalum are also suitable materials for the anode 35 current collector. In the exemplary cell of the present

5 invention, the anode component has an extended tab or
lead of the same material as the anode current
collector, i.e., preferably nickel or titanium,
integrally formed therewith such as by welding and
contacted by a weld to a cell case of conductive metal
10 in a case-negative electrical configuration.
Alternatively, the anode may be formed in some other
geometry, such as a bobbin shape, cylinder or pellet to
allow an alternate low surface cell design.

Before the previously described ϵ -phase active
15 materials are fabrication into a cathode electrode for
incorporation into an electrochemical cell, they are
preferably mixed with a binder material, such as a
powdered fluoro-polymer, more preferably powdered
polytetrafluoro-ethylene or powdered polyvinylidene
20 fluoride, present at about 1 to about 5 weight percent
of the cathode mixture. Further, up to about 10 weight
percent of a conductive diluent is preferably added to
the cathode mixture to improve conductivity. Suitable
materials for this purpose include acetylene black,
25 carbon black and/or graphite or a metallic powder such
as of nickel, aluminum, titanium and stainless steel.
The preferred cathode active mixture thus includes a
powdered fluoro-polymer binder present at about 3 weight
percent, a conductive diluent present at about 3 weight
30 percent and about 94 weight percent of the cathode
active material. For example, depending on the
application of the electrochemical cell, the range of
cathode compositions is from about 99% to about 80%, by
weight, ϵ -phase silver vanadium oxide mixed with carbon
35 graphite and PTFE.

100-200-300-400-500-600-700-800-900-1000

5 Cathode components for incorporation into an
electrochemical cell according to the present invention
may be prepared by rolling, spreading or pressing the
cathode active materials onto a suitable current
collector selected from the group consisting of
10 stainless steel, titanium, tantalum, platinum, gold,
aluminum, cobalt-nickel alloys, nickel-containing
alloys, highly alloyed ferritic stainless steel
containing molybdenum and chromium, and nickel-,
chromium- and molybdenum-containing alloys. The
15 preferred current collector material is titanium and,
most preferably, the titanium cathode current collector
has a thin layer of graphite/carbon material, iridium,
iridium oxide or platinum applied thereto. Cathodes
prepared as described above may be in the form of one or
20 more plates operatively associated with at least one or
more plates of anode material, or in the form of a strip
wound with a corresponding strip of anode material in a
structure similar to a "jellyroll".

 In order to prevent internal short circuit
25 conditions, the cathode is separated from the Group IA,
IIA or IIIB anode by a suitable separator material. The
separator is of electrically insulative material, and
the separator material also is chemically unreactive
with the anode and cathode active materials and both
30 chemically unreactive with and insoluble in the
electrolyte. In addition, the separator material has a
degree of porosity sufficient to allow flow there
through of the electrolyte during the electrochemical
reaction of the cell. Illustrative separator materials
35 include fabrics woven from fluoropolymeric fibers

5 including polyvinylidene fluoride,
polyethylenetetrafluoroethylene, and
polyethylenechlorotrifluoroethylene used either alone or
laminated with a fluoropolymeric microporous film,
non-woven glass, polypropylene, polyethylene, glass
10 fiber materials, ceramics, a polytetrafluoroethylene
membrane commercially available under the designation
ZITEX (Chemplast Inc.), a polypropylene membrane
commercially available under the designation CELGARD
(Celanese Plastic Company, Inc.) and a membrane
15 commercially available under the designation DEXIGLAS
(C.H. Dexter, Div., Dexter Corp.).

The electrochemical cell of the present invention
further includes a nonaqueous, ionically conductive
electrolyte which serves as a medium for migration of
20 ions between the anode and the cathode electrodes during
the electrochemical reactions of the cell. The
electrochemical reaction at the electrodes involves
conversion of ions in atomic or molecular forms which
migrate from the anode to the cathode. Thus, nonaqueous
25 electrolytes suitable for the present invention are
substantially inert to the anode and cathode materials,
and they exhibit those physical properties necessary for
ionic transport, namely, low viscosity, low surface
tension and wettability.

30 A suitable electrolyte has an inorganic, ionically
conductive salt dissolved in a nonaqueous solvent, and
more preferably, the electrolyte includes an ionizable
alkali metal salt dissolved in a mixture of aprotic
organic solvents comprising a low viscosity solvent and
35 a high permittivity solvent. The inorganic, ionically

5 conductive salt serves as the vehicle for migration of the anode ions to intercalate or react with the cathode active material. Preferably, the ion forming alkali metal salt is similar to the alkali metal comprising the anode.

10 In the case of an anode comprising lithium, the alkali metal salt of the electrolyte is a lithium based salt. Known lithium salts that are useful as a vehicle for transport of alkali metal ions from the anode to the cathode include LiPF_6 , LiBF_4 , LiAsF_6 , LiSbF_6 , LiClO_4 ,
15 LiO_2 , LiAlCl_4 , LiGaCl_4 , $\text{LiC}(\text{SO}_2\text{CF}_3)_3$, $\text{LiN}(\text{SO}_2\text{CF}_3)_2$, LiSCN , LiO_3SCF_3 , $\text{LiC}_6\text{F}_5\text{SO}_3$, LiO_2CCF_3 , LiSO_6F , $\text{LiB}(\text{C}_6\text{H}_5)_4$, LiCF_3SO_3 , and mixtures thereof.

Low viscosity solvents useful with the present invention include esters, linear and cyclic ethers and
20 dialkyl carbonates such as tetrahydrofuran (THF), methyl acetate (MA), diglyme, triglyme, tetraglyme, dimethyl carbonate (DMC), 1,2-dimethoxyethane (DME), 1,2-diethoxyethane (DEE), 1-ethoxy,2-methoxyethane (EME), ethyl propyl carbonate, methyl propyl carbonate, ethyl
25 propyl carbonate, diethyl carbonate, dipropyl carbonate, and mixtures thereof. Suitable high permittivity solvents include cyclic carbonates, cyclic esters and cyclic amides such as propylene carbonate (PC), ethylene carbonate (EC), butylene carbonate (BC), acetonitrile,
30 dimethyl sulfoxide, dimethyl, formamide, dimethyl acetamide, γ -valerolactone, γ -butyrolactone (GBL), N-methyl-pyrrolidinone (NMP), and mixtures thereof. In the present invention, the preferred anode is lithium metal and the preferred electrolyte is 0.8M to 1.5M
35 LiAsF_6 or LiPF_6 dissolved in a 50:50 mixture, by volume,

5 of propylene carbonate as the preferred high
permittivity solvent and 1,2-dimethoxyethane as the
preferred low viscosity solvent.

10 The preferred form of a primary alkali metal/solid
cathode electrochemical cell is a case-negative design
15 wherein the anode is in contact with a conductive metal
casing and the cathode contacted to a current collector
is the positive terminal. The cathode current collector
is in contact with a positive terminal pin via a lead of
the same material as the current collector. The lead is
welded to both the current collector and the positive
terminal pin for electrical contact.

20 A preferred material for the casing is titanium
although stainless steel, mild steel, nickel-plated mild
steel and aluminum are also suitable. The casing header
comprises a metallic lid having an opening to
accommodate the glass-to-metal seal/terminal pin
feedthrough for the cathode electrode. The anode
electrode is preferably connected to the case or the
25 lid. An additional opening is provided for electrolyte
filling. The casing header comprises elements having
compatibility with the other components of the
electrochemical cell and is resistant to corrosion. The
cell is thereafter filled with the electrolyte solution
described hereinabove and hermetically sealed such as by
30 close-welding a titanium plug over the fill hole, but
not limited thereto. The cell of the present invention
can also be constructed in a case-positive design.

35 It is appreciated that various modifications to the
inventive concepts described herein may be apparent to
those of ordinary skill in the art without departing

5 from the spirit and scope of the present invention as defined by the appended claims.